

# Progress made in managing and valuing ecosystem services: a horizon scan of gaps in research, management and governance



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## ABSTRACT

Sustaining functional ecosystems that provide services for human well-being is a global challenge. This makes valuing ecosystem services and managing them important to ensure benefits to the environment and livelihoods. Strides have been made in research and knowledge development, policy formulation and the implementation of natural resource management (NRM) programs and investment into ecological (green) infrastructure globally. However, further funding is needed for such programs to be scaled up and adapted to local contexts. Horizon scanning is a useful approach to identify future trajectories, and to guide research, policy formulation and management implementation, as well as to identify gaps. Past achievements, gaps and future needs in relation to “optimising and unlocking investment in ecological infrastructure and valuing ecosystem services” were identified through a free listing questionnaire and a group workshop exercise by 44 participants involved in an international workshop. The 10 key needs raised were all closely interlinked and fall under the overarching themes of research and assessment, policy formation and implementation, strategic planning as well as management and governance of the policy/adaptive management cycle. We discuss the need to overcome these gaps in the context of South Africa and in relation to other countries globally.

## 1. Introduction

Globally, ecosystem services have been recognised as a way to communicate the importance of maintaining natural capital as a base for human well-being (Norgaard, 2010; Lele et al., 2013). Hence, conservation programs, management initiatives and landscape restoration at multiple spatial scales is important to ensure improved supply and sustainable use of these services (Costanza et al., 1997; Higgins et al., 1997; UN, 2010; Sabogal et al., 2015). To ensure the sustainable supply of ecosystem services, functional ecological (SANBI, 2014) or green (European Commission, 2013a) infrastructure is needed. These terms refer to naturally functioning ecosystems and cultural landscapes that deliver valuable services to people (WWF and AfDB, 2012; Aronson and Alexander, 2013; Garrido et al., 2017). Ecosystems and cultural landscapes are being degraded and threatened, thus investments into functional ecological (green) infrastructure is needed to maintain biodiversity and to sustain the provision of ecosystem services, important for poverty alleviation and development (de Groot et al., 2013; SANBI, 2014). This is in line with global policies

such as the Aichi targets (CBD, 2010) and the UN Sustainable Development Goals. Maintenance of functional ecological infrastructure needs to be integrated into the spatial planning and expenditure of a range of government departments along with other stakeholders, such as the private sector, and requires national and transnational planning to make it work (SANBI, 2014; Angelstam et al., this issue). For example, South Africa has made several investments to sustain ecological infrastructure also termed natural resource management (NRM) to aid poverty relief and improve the supply of ecosystem services. This includes programs such as Working for Water (WfW) (van Wilgen and Wannenburgh, 2016) and the introduction of systematic conservation planning (Pressey et al., 2003) run at a large national scale. Despite this, key gaps in knowledge and inadequate implementation act as barriers to effective NRM in South Africa (Shackleton et al., 2016; Angelstam et al. this issue). Similarly, the Weeds of National Significance (WoNS) program in Australia aims to systemically manage invasive species to reduce their negative impacts on biodiversity, ecosystem services, and human well-being and shows mixed success (Raphael et al., 2010). In accordance with international

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and EU policies and directives a key target of the national environmental policy in Sweden is to maintain functionality of ecosystems in the long term (SOU, 2013). To guide environmental legislation and spatial planning Sweden has recently established 16 environmental quality objectives. The aim is to restore and maintain functional landscapes for conservation, use, and to secure the long-term delivery of ecosystem services, as facilitated by functional green infrastructure (Jaeger et al., 2011; SOU, 2013), however, this is a considerable task and may face many barriers. Furthermore, local scale community based natural resource management (CBNRM) programs exist globally and have shown many successes and failures (Dressler et al., 2010).

Vast strides have been made towards recognising the importance of conserving ecosystem services and implementing NRM, however, globally many attempts to do so are fraught with issues (e.g., Angelstam et al., 2011a, Halme et al., 2013). Therefore, this study aims to (1) identify and review past achievements, and (2) to identify, gaps and future needs in research, management and governance to improve the efficiency in sustaining the supply of ecosystem services. We apply the horizon scanning method to review the achievements in NRM and valuing ecosystem services during the past two decades, and present results on stakeholders' perceived future needs (Sutherland et al. 2010). We discuss these achievements and needs, drawing in particular from the South African context, but also using global case studies to show similarities and differences internationally. South Africa represents many African countries with extremely rich biodiversity that are at risk, boasting at least three global biodiversity hotspots (Myers et al., 2000). These are as are under threat from many global direct and indirect drivers (Richardson et al., 1999; Wynberg, 2002). Additionally, South Africa is a developing nation, and many communities are still heavily reliant on ecosystem services for their livelihoods which is also common elsewhere in the world (Le Maitre et al., 2000; Shackleton et al., 2007). Ecosystem services also play an important role in sustaining regional and national economies, both in South Africa and globally (Blignaut et al., 2008; Reyers et al., 2015). As in other countries, maintenance and investment into ecological infrastructure and ecosystem services is crucial in South Africa (Meredith, 2005); and there is a need to introduce and improve sustainability science research (Kates, 2011) and management as well as their connection with policy and governance (e.g., King and Thomas, 2007; Sutherland et al., 2010; Shackleton et al., 2011; Bengston, 2013). Looking forward is of particular importance in the rapidly changing world that we live in, and in the context of the high pressures the environment is facing today from many different direct and indirect drivers (Sutherland et al., 2010; Rockström et al., 2009; Bengston, 2013).

## 2. Horizon scanning as a research process

Horizon scanning for the future is the formal process of gathering, processing and disseminating information to support decision making in the future (Sutherland et al., 2010; Charest, 2012). Various methods exist to conduct horizon scans. All comprise of either questionnaires and workshops or a combination conducted in various forms and some have also used trees, literature searches, trend analysis and scenario planning (Sutherland and Woodroof, 2009; Sutherland et al., 2010; Bengston, 2013). The horizon scanning process used included two phases, a questionnaire and an open forum workshop with international experts, to identify future issues/needs. Further, literature was consulted to supplement findings and to draw comparisons between South Africa and other countries (Sutherland and Woodroof, 2009; Bengston, 2013).

### 2.1. Questionnaire

An Ecosystem Services Partnership Atelier workshop that was held at Shelly Point - St Helena Bay, South Africa from the 15th to the 19th

of November 2015 was used to build the case for further investment and optimization of NRM and valuing ecosystem services. The theme focused on “optimising and unlocking investment in ecological infrastructure and valuing ecosystem services in South Africa”. This workshop involved 44 international participants from a range of countries and backgrounds, and represented government policy makers and managers (21), researchers from a variety of natural and social science disciplines (20) and representatives from the media (4), private sector (4) and various NGO's (6) with some participants straddling more than one discipline. At the meeting a questionnaire was distributed, which focused on (1) past achievements and (2) future needs. It was answered by 34 (out of 44) participants.

### 2.2. Open forum workshop

The participatory workshop was used for definition and revision of key sub-themes which arose from the questionnaire responses (Farley et al., 2009). Key themes emerging from the questionnaire data were grouped and then workshoped by all participants on the last day of the meeting. A lot of focus was placed on South Africa in particular, however, all of the issues raised were globally relevant and were widely discussed by international and South African participants drawing from examples and knowledge internationally. We summarised the past achievements into five main themes, and we present and discuss the five past successes and the 10 most commonly raised issues/needs relating to investing in and implanting NRM as well as valuing ecosystem services. Both the past achievements and future needs were supplemented by a review of literature. Additionally, informant interviews were made with the workshop organisers and facilitators to acquire information and input.

## 3. Results

### 3.1. Past achievements

Strides have been made in the last two decades on understanding global environmental issues (e.g., Ostrom, 2009; Rockström et al., 2009; Kumar, 2010), including understanding the value and role of ecosystem services and how to manage and restore them (Costanza et al., 1997; Millennium Ecosystem Assessment, 2005). In addition there has been a substantial rise in the number of national NRM projects being implemented (e.g. WoNS in Australia (Thorp and Lynch, 2000)) and many projects globally (Dressler et al., 2010), and South Africa boasts the internationally acclaimed Working for Water project (van Wilgen and Wannenburgh, 2016). Here we present five past successes that were highlighted in relation to “optimising and unlocking investment in ecological infrastructure and valuing ecosystem services” drawing on South African and global perspectives.

#### 3.1.1. Increase in the research base and understanding

Globally, more than 2000 papers are published annually relating to ecosystem services. The participants discussed that the increased volume of research over the past two decades has drastically improved our understanding of ecosystem services globally. It has also led to improvements in scientific techniques and tools relating to ecosystem service research, valuation and management. Some important strides that have been made internationally include identifying the value of ecosystem services and their importance for human well-being (Costanza et al., 1997; Millennium Ecosystem Assessment, 2005). In particular large steps have been made in the theory of how to value ecosystem services using different techniques such as GIS based methods, system dynamic modelling, and survey based economic valuation approaches such as willingness to pay and direct use valuation (Boyer and Polansky, 2004; Hein et al., 2006; Tietenberg and Lewis, 2010; Vo et al., 2012). Many respondents mentioned that on a global level we are also learning about the role ecosystem services

play in social-ecological systems and how they are fraught with complexity - making integrative and transdisciplinary research necessary. Additionally, there are multiple pressures driving degradation of ecosystem services. Investment in NRM, including its governance, is therefore important to conserve biodiversity and to support human well-being and economic growth (Higgins et al., 1997).

South Africa has been party to some seminal research on ecosystem services and their management during the past 20 years. These include valuing ecosystem services and potential losses through degradation, thus building the case for investment in NRM on a large spatial extent (Higgins et al., 1997; Le Maitre et al., 2000; Blignaut et al., 2008). In addition, finer scale valuation of the importance of natural resources for rural livelihoods, in particular as safety nets during times of vulnerability, has been driven in South Africa (Shackleton et al., 2007), but also understanding the importance of cultural ecosystem services for local communities (Dold and Cocks, 2012). South Africa also has a large body of research focusing on the drivers of degradation within ecosystems, and their negative impacts on ecosystem services and human well-being. This includes the impacts of invasive species on numerous services (Higgins et al., 1997; Le Maitre et al., 2000; Le Maitre et al., 2011), climate change impacts and adaption responses (Thomas et al., 2007), overgrazing impacts (Todd and Hoffman, 1999) and bush encroachment (Hoffman et al., 1999; Hoffman and Todd, 2000). South Africa has also been in the forefront on producing research on NRM and landscape restoration approaches and strategies (Richardson et al., 2007; van Wilgen et al., 2001, 2011) as well as environmental assessment and conservation planning (Balmford, 2003; Cowling et al., 2003, 2008; Driver et al., 2003; Pierce et al., 2005).

### 3.1.2. Availability of data sets for research and NRM implementation

Participants identified that many data sets are important for research and implementation of NRM projects and valuing ecosystem services and are increasing in availability. Some important international data sets for research on ecosystem services and NRM include the TEEB Ecosystem Services Valuation Database (Van der Ploeg and De Groot, 2010), and the global land-cover data set developed by the US Geological Survey (Sutton and Costanza, 2002) used commonly for studying ecosystems, and for valuing ecosystem services globally (e.g. de Groot et al., 2012; Costanza et al., 2014). Other useful global data sources services and developing management programs include satellite images available through the USGS Earth Explorer, UNEP Environmental Data Explorer, FAO GeoNetwork, ISCGM Global Map, Earth Data, Global Forest Watch and the WorldClim database. Advances in the use of GIS software programs have also been highly beneficial.

The build-up of spatial land cover and socio-economic data sets over the past two decades has been highly beneficial for research on ecosystem services in South Africa, but also for spatial planning to guide NRM management (Egoh et al., 2008). Some of these include the Department of Water Affairs and Forestry (DWAF) ground and surface water database, vegetation cover of South Africa, soil erosion potential (Schoeman et al., 2002; Le Roux et al., 2008), land capability and carbon sequestration maps (Driver et al., 2005), which have been used for the analysis of ecosystem services and planning NRM by Egoh et al. (2008) and Blignaut et al. (2013). Egoh et al. (2008) also produced an ecosystem service production spatial data set for South Africa. The nationally available aerial imagery, topographic, elevation, land cover, vegetation types and Agricultural Georeferenced Information System are data sets that are frequently used for ongoing NRM planning. In addition, human population census data produced by Statistics South Africa has been used for ecosystem services research and conservation planning such as in Blignaut et al. (2013).

### 3.1.3. Progressive policy

Participants identified that progress has been made to build good policy relating to investment in ecological infrastructure and NRM.

Global policy and international agreements, which explicitly or implicitly encompass ecosystem and environmental conservation as well as sustainability are growing. This includes international agreements such as Agenda 21, the Kyoto protocol, the Convention on Biodiversity, UN Sustainability Goals, the International Convention for the Control and Management of Ships' Ballast Water and Sediments and the World Commission on Dams - in which many countries are signatories. The requirements of these agreements have actively been built into policy at national and local scales worldwide (Shackleton et al., 2011). In addition, South Africa is considered to be a world leader in producing policy which addresses environmental sustainability, conservation and ecosystem services (van Wilgen and Wannenburgh, 2016). This is encompassed in the National Development Plan (NDP), local Integrated Development Plans (IDP's) and the National Environmental Management: Biodiversity Act (NEM: BA) 2004, and the role of the environment and its services is embodied strongly in the South African Constitution. This has enabled South Africa to produce projects such as WfW which is comparable to WoNS in Australia. Furthermore, guided by EU policy, Swedish policy is pushing strongly towards ensuring long term sustainable ecosystems (SOU, 2013). Environmental Impact Assessments (EIA) requirements are also very stringent in South Africa, however, adherence could be improved (Wood, 1999). At the same time, in spite of strong policy there is a lack of enforcement and many barriers to implementation which are linked to financial and capital restrictions, red tape, political time frames and agendas and incorrect indicators (Shackleton et al., 2011; Angelstam et al., this issue). Good policy with a lack of implementation is commonplace around the world including South Africa but also many developed nations (e.g., Angelstam et al., 2011a; Blicharska et al., 2011).

### 3.1.4. Buy in for investment in ecological infrastructure and NRM implementation

Globally there are many large scale international (Thorp and Lynch, 2000) and smaller scale projects (Dressler et al., 2010), aimed at investment in ecological infrastructure and preserving the supply of ecosystem services (see also European Commission, 2013b). Certain sectors in South Africa have worldclass NRM programs, and there is high buy in from the state in particular. This has led to the creation of numerous NRM “working for” projects. The primary one is the WfW program which focuses on clearing invasive alien species in the country. Key to this substantial buy in and investment from the state has been promoting these NRM projects as having dual goals (van Wilgen and Wannenburgh, 2016). These goals include (1) improving the supply of ecosystem services and (2) the creation of jobs aiding poverty alleviation, particularly in rural areas of South Africa. The second goal has acted as a “hook” for state investment into these “working for” programs. The WfW project similar to the WoNS program in Australia, but with a focus on social goals as well as ecological ones. However, globally there is still a lack of investment and implementation of NRM in the private sector, and this needs to be addressed to improve success in NRM.

### 3.1.5. Capacity building

There has been rapid capacity growth in the field of ecosystem services and NRM globally. This is illustrated by the exponential increase in publications in the field over the last 10 years. For example, a review by Liqueste et al. (2013) shows that work on marine and coastal ecosystem services has increased exponentially across the world over the past decade. In the Indo-Pacific suitability projects have been highly beneficial to help build local capacity and collaboration in protecting marine ecosystems (Christie et al., 2016). The growth of NRM investment and research in South Africa has aided substantially in building capacity in the field. The WfW program in particular has grown from implementing 10 projects in 6 provinces in 1996 to over 300 in all nine provinces of South Africa in 2015 (van Wilgen and

Wannenburgh, 2016). This has been highly beneficial for providing a practical skill set for thousands of unskilled workers. The number of jobs created in the WfW program has increased from 2000 in 1995 to 12000 in 2012 (van Wilgen and Wannenburgh, 2016). In addition environmental modules and awareness are increasingly incorporated with other disciplines in South Africa and globally (Shackleton et al., 2011). There are still, however, capacity issues at higher levels especially in developing nations (Shackleton et al., 2016), but this should improve in time as budgets continue to grow and more people are trained with relevant skill sets.

3.2. Gaps and future needs

Although great strides have been made with regard to understanding and valuing ecosystem services and investing in NRM there are still major gaps. Numerous future needs with regards to optimising and securing investment for NRM and valuing ecosystem services were identified using horizon scanning at the international workshop. Here we present and discuss the top 10 issues identified. There are many links/interconnections between the 10 topics; nevertheless they fall under the overarching themes of research and assessment, policy formation and implementation, strategic planning and management, and governance found within the policy/adaptive management cycle (Fig. 1).

3.2.1. Further research in key areas “filling in the gaps”

While research on ecosystem services and NRM has grown substantially since the 1990s (in total more than 10000 papers published

in English globally) and many advances have been made, there are still many topics that need further research. These topics need to consider knowledge production and learning about both ecological and social systems, how they interact, and include different actors and stakeholders (e.g., Angelstam et al., 2013a, Angelstam et al., 2013b; Singh et al., 2012; Hirsch Hadorn et al., 2008) in the questionnaire and the workshop included the following; quantifying the benefits of different kinds of landscape restoration, long-term monitoring providing an empirical evidence base to assess status, trends and benefits of ecological infrastructure (a need highlighted below), desired short- and long-term performance targets, developing financial modelling tools for private investment in ecological infrastructure and how to better link ecosystem services, sustainability and human well-being. Some more specific areas which need focus is how to accurately value different landscapes - wet vs. dry lands and different land tenures, the development of robust and transparent conflict resolution methods in the field of NRM, having dynamic models linked to a game interfaces, valuing carbon in ecosystem service assessments and how ecosystem service generation relates to ecosystem service state. Filling in these gaps will allow further growth of management and investment towards functional ecological infrastructure covering representative terrestrial and aquatic ecosystems globally.

3.2.2. Better indicators and monitoring (evidence base of NRM)

There is a great need for long-term monitoring of the supply and demand of ecosystem services, and the consequences of NRM projects/ investment in ecological infrastructure (Fig. 1), a point many participants suggested is lacking. This is further highlighted in Popescu et al.

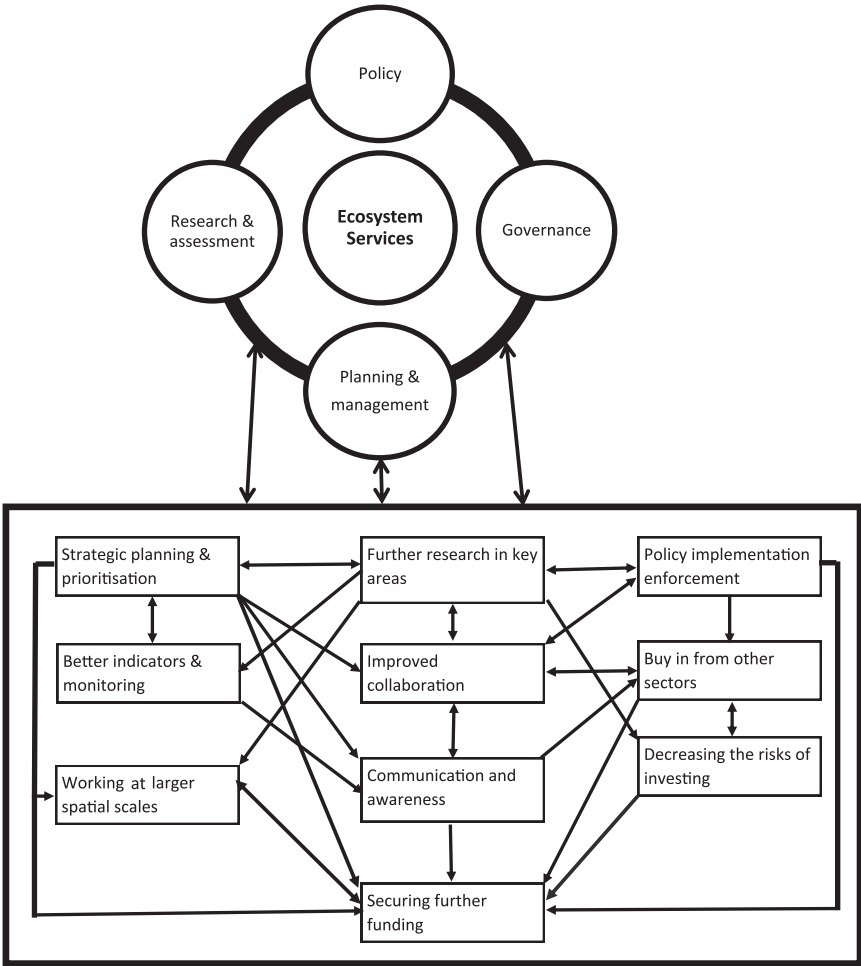


Fig. 1. : Schematic showing the need for improved interaction between the adaptive management cycle and the need to improve investment and optimisation of ecological infrastructure development/management.



(2014), who discuss that assessment of policy implementation processes is often limited. This is linked to the above statement (Section 3.2.1) of needing more evidence-based knowledge from long-term monitoring about both ecological and social systems. Currently in South Africa the WfW program has been in operation for almost 20 years. However, there is a severe lack of evidence of the benefits that clearing of invasive species has had on the change in the supply of ecosystem services (van Wilgen and Wannenburgh, 2016). Furthermore, flawed indicators of success are being used such as, the number of hectares cleared and number of jobs created rather than benefits to biodiversity, ecosystem services and human well-being (Shackleton et al., this issue). The status of the environment in areas where NRM work has been done is also largely not monitored and so the benefits of restoration work is unknown (van Wilgen and Wannenburgh, 2016). This issue is not unique to South Africa and inadequate monitoring plagues many social-ecological management related projects internationally – especially over long time frames (Turner et al., 2016). For example, globally there are poor indicators for provisioning and cultural services, service flow and benefits of management with regards to marine and coastal ecosystem services (Liquete et al., 2013). Zhang et al. (2010) recognise there is lack of standardisation of indicators relating to ecosystem service assessments in China. Similar issues regarding long-term monitoring have been raised for the WoNS project in Australia also tasked with managing invasive species (Reid et al., 2009; Raphael et al., 2010). Furthermore, inadequate monitoring is commonplace in river restoration projects in Australia (Brooks and Lake, 2007), and poor monitoring has been seen as a key factor inhibiting forest governance in New Zealand (Levack, 2006). Having evidence-based about states and trends knowledge is crucial with regards to strategic planning of restoration work, raising funding and promoting collaboration. One reason for this limitation – particularly relevant in South Africa – is the fact that metrics relating to job creation in NRM have taken precedence over restoring the environment, leading to the subsequent lack of relevant monitoring (van Wilgen and Wannenburgh, 2016). Additionally, monitoring is time consuming and costly and often needs to be conducted once projects are completed – for significant lengths of time. Hence, cost effective but reliable indicators need to be identified to enable efficient monitoring about both ecological and social systems. It is vital that better monitoring takes place in the future as it will be highly beneficial to providing evidence to secure funding over the long run and especially to promote buy in from different sectors. Good indicators and well-designed monitoring and evaluation systems are integral for good project management and adaptive management programs (Stem et al., 2005). Busch and Trexler (2003) describe three types of monitoring: implementation, validation and effectiveness. The first is exemplified by national and international processes to develop criteria and indicators (Van Buren and Blom 1997). The second involves assessment of the extent to which indicators actually measure the phenomenon in focus (Angelstam et al., 2013b). The third aims at quality assurance, for example in the context of adaptive management in landscapes as social-ecological systems.

### 3.2.3. Improved communication and awareness among sectors

Knowledge of the environment, ecosystem services and their importance for humans and thus the need for management is evident. According to the respondents, there is, however, only a small group of people who really know and understand this internationally, and it is of extreme importance that we get broader audiences to understand the role of ecosystem benefits for human well-being and the environment. This is an important factor which could raise buy in from lay communities and industry. One of the main issues contributing to this lack of awareness and communication is that scientists communicate their research in closed access journals denying availability to broader audiences. More needs to be done to make information available (Knight et al., 2008). For example, social media has been important

for the governance of agro-food sustainability (Stevens et al., 2016) and needs to be adopted more in the field of ecosystem services and NRM. A push needs to be made to get scientists to publish more popular press articles or to collaborate more with journalists to make the key findings accessible to the general public, planners and policy makers. In addition, there is also a lack of communication among actors and stakeholders involved in NRM projects (Shackleton et al., 2016). Improving the transdisciplinary nature of research and project implementation will greatly improve communication and awareness. This is a challenge to both academic and non-academic participants and their organisations (e.g., Angelstam et al., 2013a; Turner et al., 2016).

An important factor relating to communication and awareness building is framing, which can have a significant implication on how messages are received (Davis, 1995; Carter and Currie-Alder, 2006). It is important that “hooks” are found to improve awareness and aid better communication. For example, in South Africa a campaign to reduce the spread of HIV initially focused on the negative effects of the disease and was unsuccessful. However, it was later reframed as “The Love Life” campaign which yielded better results. Similarly changing the use of the terms “natural resource or environmental management” to “investment in ecological infrastructure” has substantially improved interest from the industrial and business sectors in South Africa. However, the biggest success has been framing invasive clearing projects as “Working for Water” by putting emphasis on job creation to get buy in from the state leading to large investments for clearing invasive species in catchments (van Wilgen and Wannenburgh, 2016). The employment of media and marketing representatives within large scale NRM projects can aid substantially in getting the message across to different sectors of society. This needs to be done on a larger scale within South Africa and globally to improve awareness and buy in from the public. This large-scale awareness is the only way that buy in will grow and increase investment into NRM will be achieved – correct and effective communication is key.

### 3.2.4. Strategic planning and prioritisation

Although relevant policy is in place and there are many active programs involved in NRM, many are applied in an ad hoc manner, thus reducing efficiency (van Wilgen and Wannenburgh, 2016). The lack of strategic planning was highlighted as a major barrier by workshop participants. This leads to inefficient use of limited resources. Therefore, strategic planning and prioritisation is important to guide investment in NRM and to maximise efficiency (Wilson et al., 2006). Various approaches are available to develop strategies and prioritise areas for inclusion into ecological infrastructure. These include collaborative learning, scenario planning, multiple stakeholder workshops and desktop based spatial planning or a combination of these approaches (Bohensky et al., 2006; Grice et al., 2011; Forsyth et al., 2012; Anderson et al., 2013a,b; Axelsson et al., 2013; Shackleton et al., this issue). This realisation is slowly being met in South Africa and reports have been produced on National Fresh Water Ecosystem Priority Areas (Nel et al., 2011), and Critical Biodiversity Areas (CBA's) are being developed (Holness and Bradsahw, 2010). Furthermore, examples of invasive species specific strategies and management plans are emerging (van Wilgen et al., 2011; Shackleton et al., this issue). In Australia the WoNS program produced strategic plans to manage 20 key invasive species to improve successes and has benefited overall control (Thorp and Lynch, 2000). There is an urgent need for developing approaches to integrated cross-sectoral spatial planning towards functional ecological (green) infrastructure. Holistic, landscape-scale planning therefore needs to be promoted within NRM (Sitas et al., 2014). However, land tenure, including land ownership rights, provide critically important challenges for landscape stewardship. This could be addressed through building better partnerships and awareness, another key topic of need (see Sections 3.2.6 and 3.2.7).

### 3.2.5. Policy implementation and enforcements

Although many countries have sound policy many of these policies lack implementation and enforcement. Internationally, environmental policy often takes a back seat in relation to developmental policy (Blicharska et al., 2011) and stakeholder engagement is difficult to secure (Elbakidze et al., 2015). According to the respondents and the key informant interviews, while South Africa has produced world class policy and is signatory to many global agreements relating to NRM, actual implementation and enforcement of these policies within South Africa is poor. For example, under national policy, local and district municipalities are required to include policy to address environmental issues and sustainability in their local integrated development plans (IDPs), however, the majority of municipalities in South Africa have little to no coverage of these issues (Ruwanza and Shackleton, 2015). This is mainly due to the fact that there is a lack of capacity at the local level, but also because the environment is considered a green issue by most and not incorporated with in the holistic social-ecological context (Shackleton et al., 2011). In addition, under the NEM: BA act 2004, regulations on invasive species legally require private land owners to clear their land of certain invasive species which is not being enforced or regulated (Shackleton et al., 2016). Poor enforcement is commonplace in many other environmentally related legal and policy requirements (Ruwanza and Shackleton, 2015). Similar trends in poor implementation are seen elsewhere. In Brazil, for example, corruption is closely linked to poor policy implementation and lack of adherence to environmental laws and is commonplace in many developing nations (Aklin et al., 2014). Jordan (1999) also highlights poor implementation of environmental policy in developed nations within the EU. Enforcement of policy and law around Marine Protected Areas (MPA's) in the Indo-Pacific is also lacking (Christie et al., 2016). Improved enforcement and implementation of legislation will improve NRM in the long run through increased buy in from private land owners and state departments, however, awareness needs to be built and capacity improved. Monitoring will also need to be improved to assess compliance which is lacking globally (e.g. Busch and Trexler, 2003; Angelstam et al., 2011). Furthermore, more needs to be done to develop integrative policy formation with multiple stakeholders, which can be highly beneficial in the long run as seen from a case study in Argentina (Cáceres et al., 2016).

### 3.2.6. Improved collaboration among sectors at multiple levels of governance

There are still major issues with the lack of collaboration among sectors and actors at different levels of governance. Globally research is still conducted primarily in a disciplinary fashion with a lack of integration (Max-Neef, 2005). Collaborative learning between researchers and practitioners at multiple levels is also limited (e.g. Axelsson et al., 2013). Thus, stakeholders are not consulted and involved in knowledge production, learning and development of NRM projects. This is lacking as transdisciplinary research can face many problems (Angelstam et al., 2013a; Fraser et al., 2006; Reyers et al., 2009; Turner et al., 2016). For example, in South Africa, government departments with overlapping mandates are not collaborating and communicating which has been identified as a major barrier to the effective implementation of NRM programs (Shackleton et al., 2016). This is also seen in a multitude of examples elsewhere in the world (Turner et al., 2016). Improving the transdisciplinary nature of research and NRM project planning will greatly improve successes in the long run and make research more relevant (Max-Neef, 2005; Angelstam et al., 2013a; Sitas et al., 2014). In addition, further collaboration will improve buy in from different sectors. This has been identified by the respondents as a major need going forward and needs to be addressed for scaling up NRM programs internationally (Carter and Currie-Alder, 2006; Reyers et al., 2015). Improving governance collaboration between different stakeholders can be done, as seen in a case study in the Indo-Pacific, however, it takes a lot of dedication and

faces many barriers (Christie et al., 2016).

### 3.2.7. Buy in from other sectors

Globally, most funding for investment into ecological infrastructure comes from the state. If investment into ecological infrastructure is to be made more sustainable there needs to be buy in from other stakeholders, particularly the private sector. Currently in South Africa NRM is driven by the state funded “working for” programs. There has been a substantial increase in private sector investment in ecotourism, which links strongly to the conservation of biodiversity and ecosystem services (Sims-Castely et al., 2005; European Commission, 2013b). However, there is still a lack of buy in from other sectors, such as private industry and the public as highlighted by workshop participants. However, there is growing awareness of the need for holistic and multi-sectoral investment in NRM (Reyers et al., 2015). For example, private insurance companies are realising the role of ecosystem services in disaster risk management and are investing in research and management (Reyers et al., 2015). Additionally, national brewing companies now understand the importance of water supply for the sustainability of their business, and are starting to invest in catchment management (Reyers et al., 2015). Promoting and optimising Payment for Ecosystem Services (PES) to improve buy in and valuation of ecosystem services globally is a key requirement to improve investment into managing ecosystem services globally over the long run (Jacka et al., 2008). Enforcement of policy will also help to incentivise buy in from state departments, private land owners and industry. Cumming et al. (this issue) highlight how investment into ecological infrastructure is important to meet the SDGs and highlights ways of securing private funding.

### 3.2.8. Decrease the risk of investing in NRM and ecological infrastructure

Reducing the risk of investing in NRM is important for getting buy in from other stakeholder groups and is key for building NRM funding globally. However, there is still a lack of knowledge on what drives risk, which hinders further investment (Blignaut et al., 2013). Returns on investment is a key consideration for any investor and uncertainty in the NRM sector also makes investments risky (Mugido et al., 2014). More needs to be done to show that investment into ecological infrastructure can substantially meet the interest of private companies but also falls in line with policy on development (Cumming et al., this issue). For example, a recent collaborative research project has shown the importance of investing in NRM by private insurance and brewing companies for disaster risk reduction which would help improve their long-term returns and sustainability (Reyers et al., 2015). Furthermore, research into harvesting invasive alien biomass for energy could be beneficial, and aid local development (Mugido et al., 2014).

The benefits of these case studies need to be promoted to improve broader national and global buy in. Improved natural capital accounting and other decision making mechanisms and frameworks such as system dynamic modelling along with portfolio mapping and the use of the water neutrality framework will also be crucial for reducing risks and guiding investment in NRM (Nel et al., 2008; Crookes et al., 2013; Blignaut et al., 2014). Many NRM projects face a “planning fallacy” whereby benefits are overestimated, resulting in lower than expected returns and higher risk. To overcome this it is important to conduct third party assessments to truly assess risk and where they can be decreased (Mills et al., 2015). Investment into carbon related projects is still risky due to market instability. The global carbon market is extremely sensitive to changes in policy with large fluctuations in price makes investment uncertain (Feng et al., 2012). Improving policy and compliance in the carbon market would help to reduce risk. With increased buy in the risk of investment will fall, making it important to promote private sector NRM but also to develop more tools to guide this investment to reduce risks.

### 3.2.9. Work at larger spatial extents

While a piecemeal approach is characteristic in research and development projects, it is ineffective in re-establishing/resuscitating ecosystem services on a large scale (van Wilgen et al., 2012). Ecosystems are categorised by multiple and interrelated landscapes and land uses. To be effective these projects need to be scaled up into holistic landscape and regional scale projects, which need to be implemented with mass buy in from different stakeholders (Shackleton et al., 2011; Sitas et al., 2014). Additionally, this is linked closely to effectively prioritising areas using strategic and tactical spatial planning on a broad scale to include different stakeholders and landscapes. Working on larger scales with buy in from numerous stakeholders will help to improve success of projects and reduce risks, but ways of managing the complexity that comes with this also needs to be considered and better understood (Reyers et al., 2015; Turner et al., 2016). Many NRM programs in South Africa focus on small areas such as private properties or on small parts of large catchments often in an ad hoc manner which inhibits long-term efficiency and holistic ecosystem recovery (van Wilgen and Wannenburgh, 2016). Global literature for the need to build conservation corridors for protected areas (Hilty et al., 2012) can be adopted and revised to be applied to investment in ecological infrastructure and NRM. Further understanding and managing landscapes as integrated social-ecological systems needs to be promoted. For example, Takeuchi et al. (2016) suggest that there needs to be a push to manage landscapes as integrated systems in a holistic context (*satoyama*) as was done in Japan in the past, to improve benefits and management efficiency and success.

### 3.2.10. Secure further funding

Globally, many projects struggle to acquire long-term funding to ensure their sustainability (Turner et al., 2016) and many programs rely on the state for funding. However, the state alone cannot always achieve the funding target (Angelstam et al., 2011). It is thus imperative that private sector investment is raised for NRM projects globally and is a key need highlighted for reaching the UN Sustainable Development Goals (Sachs and McArthur, 2005). In addition, investments are needed to enhance stakeholder collaboration and awareness among sectors at different levels of governance (e.g. Elbakidze et al., 2010), and monitoring of social-ecological systems (Singh et al., 2012). Addressing many of the needs identified in this paper will greatly aid in securing further funding. Many avenues exist to secure private sector investments such as; carbon markets (Mills and Cowling, 2006), companies ensuring the probability and sustainability and redoing disaster risk through managing and ensuring the ecosystem services (PES) (Sitas et al., 2014; Reyers et al., 2015) and through investments in private conservation initiatives for tourism (Sims-Castely et al., 2005). Additionally, programs focusing on ecosystem service management need to apply for international funding earmarked for investment in development, which is easily justifiable. Improving awareness and co-operation as well as better implementation of legislation is likely to result in increased buy in from private land owners and industry, and could reduce the burden on the state. For example, if natural resource management and investment into ecological infrastructure in South Africa is to be fully effective, funding needs to increase by approximately six times the amount that is currently being received which is R 1.5 billion annually (Marais, C. pers. comm).

## 4. Towards optimising and unlocking investments at multiple levels

The concept that sustainable ecosystems deliver benefits that underpin human well-being is by no means a new finding (von Carlowitz 1713/2000, Marsh, 1864, Odum, 1959). The recent revival of this notion through the term ecosystem services, stresses not only goods and ecological functions and the environment but also human well-being. This requires investment in long-term sustainable land use

and management, i.e. functional ecological infrastructures, or green infrastructures (European Commission, 2013a, European Commission, 2013b). The field of ecosystem services valuation and management has made strides globally and in South Africa over the past decades. However, there are still major gaps in knowledge and implementation, as highlighted in this study, which need to be addressed to further increase understanding and valuation of ecosystem services and investment into ecological infrastructure and optimisation of NRM. The gaps identified here are relevant to many countries globally, including South Africa, covering a broad range of social-ecological and economic contexts (e.g. Raphael et al., 2010; Liqueste et al., 2013 Aklin, 2014). All of the key needs are issues faced by developed and developing countries to varying degrees as supported by their various case studies mentioned above. South Africa is recognised as one of the world leaders in ecosystem research, policy formulation and investment into NRM, and it still faces many challenges. Therefore, it is crucial that progress is made towards reaching these needs globally, especially in light of the major international challenges and drivers we are facing today, which are expected to increase in the future such as, climate change, land transformation, economic demand, invasive species spread and population growth (Vitousek et al., 1997; Schröter et al., 2005). These aforementioned drivers, coupled with the long and/or intensive use of ecosystems, results in losses in the provision of services for humans and the environment. This calls for urgent actions to holistically manage landscapes as integrated social-ecological systems. Many of the future needs to improve investment in ecological infrastructure and valuation of ecosystem services discussed here are closely interlinked. They encompass the broad need for sustainable development as a societal process (Baker, 2006) and how this can be reached by NRM and landscape restoration (Sabogal et al., 2015). The ten needs identified here link to the four broad topics within the social-ecological systems framework. These include (1) research and assessment (knowledge production), (2) policy formation and implementation (learning), (3) strategic planning and management, and (4) governance (Fig. 1).

The promotion of transdisciplinarity can be seen as a key component in linking these various needs, and is a crucial step in the process of improving NRM efficiency, understanding and buy in (Angelstam et al., 2013b; Turner et al., 2016). The development of sustainability science as a user-inspired and multi- and interdisciplinary field of research is a response to the need for holistic knowledge production and learning towards sustainable landscapes is key (Kates, 2011). Various sectors need to come together and improve information sharing, co-production of research, co-investment, transparency and multi-level collaboration and participation if the target of increasing NRM funding is to be achieved (Currie-Alder, 2005; Reyers et al., 2015; Cáceres et al., 2016). By also including stakeholders of natural resource use systems as well as policy makers and managers, the focus is not only on knowledge production, but also on collaborative learning. Policy implementation research through evaluation of governance and planning/management in landscapes and regions is a crucial step in the progress toward agreed policy goals about sustainability through the maintenance of functional ecological or green infrastructures (e.g. European Commission, 2013a, European Commission, 2013b; Cumming et al., this issue). This requires both evaluation of the policy process, and the outcomes of this process (Fig. 1). In addition, steps need to be made to reduce the research-implementation gap to improve efficiency as well as improving awareness about research findings (Currie-Alder, 2005; Knight et al., 2008). These two steps are crucial for addressing the other key needs and making progress towards understanding, implementation planning and governance. An evaluation of the policy and management process is needed and involves the assessment of what constitutes good governance and how to optimise governance and implementation with regard to investment in ecological infrastructure. This includes assessing elements such as evidence-base for land management, progress towards collaborative learning,



and assessment of legitimate processes, and the normative aims of transparency and participation. Policy processes then need to be revised and implemented to have key outcomes. Firstly, the outputs in terms of implementation of policy tools, norms and rules to be applied by governors, planners and managers at multiple levels, and pronouncements of criteria and indicators, and short-term and long-term performance targets, as well as tactical planning and operational management approaches are needed. Secondly, the consequences of the operational implementation of strategic and tactical plans for landscape conservation, protection and restoration towards functional ecological infrastructures need to be assessed and monitored with adequate indicators. However, the assessment component in the policy implementation process is often poorly implemented globally and within South Africa and is needed to build evidence to secure further investment (Popescu et al., 2014; Stanturf et al., 2015; Shackleton et al., this issue). One solution to bridge this all together is applying a landscape approach to secure the supply of ecosystem services for local and regional development (Axelsson et al., 2011; Sabogal et al., 2015; Stanturf et al., 2015). Landscape approach is a place-based process that sustains functional social-ecological systems by; (1) production of evidence-based knowledge, and (2) cross-sectoral collaborative planning and management at multiple levels of societal steering. This involves both modification of the biophysical environment, coordination of human management of land and water, and motivating stakeholders and actors. Additionally, global processes may play a crucial role in understanding interactions between nature and people very broadly and unlocking investments at national and global levels. One example is the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) which aims at assessing the state of biodiversity and of the ecosystem services it provides to society, in response to requests from decision makers ([www.ipbes.net](http://www.ipbes.net)). However, the challenge is to make this process inclusive in terms of equal representation of experts from all countries and balance between natural and social scientists.

In addition, a comparison of policy, learning, governance and knowledge in different contexts within a country, among countries or among different continents could shed light on best practices to be adopted in different social-ecological contexts. For example, the African and European continents host a variety of different landscape histories and different governance arrangements. These differences provide opportunities to explore different social-ecological systems and their efforts towards ecosystem conservation, and thus may help to understand the effects humans have on the environment and inform best or alternate policy or governance options. Using different countries' landscapes as a "time machine" also provides us the unique opportunity to learn from the consequences of the past (Angelstam et al., 2011b) as well as understand the role of past legacies for societal steering (Elbakidze et al., 2010, 2013). Due to the large variation among African countries legacies regarding governance and landscape history (Meredith, 2005), the multiple landscape case study approach is highly relevant also to South Africa and other countries, and could shed light on future management options.

## 5. Conclusion

This paper identifies and discusses ten of the main gaps/issues raised in a transdisciplinary international workshop related to optimising NRM and unlocking further investment in ecological infrastructure and better valuation of ecosystems. For the successful stimulation of investment in and optimization of ecological infrastructure, NRM will have to address some of the key challenges related to communication, interdisciplinarity, transparency, knowledge production, learning, planning, monitoring, governance and law enforcement. These challenges will take time to be addressed, but the sooner we start, the sooner we can advance NRM for human well-being and the environment and reach the target of raising R9 billion annually for NRM

projects in South Africa. If this is achieved South Africa could then be used as a model to address similar issues elsewhere in the world. It is crucial that these needs are met as they are underpinned in global and national policy and can make strides in addressing the Millennium Development Goals and the Sustainable Development Goals and will greatly aid livelihoods and biodiversity (Sachs and McArthur, 2005).

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